

Complexity of Information Systems and Bank Size: A Case Study of Croatian Banks

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Abstract. *Technological change often promotes higher complexity which in turn increases controllability issues and likelihood that something will go wrong.*

This article explores relationship between size of assets and complexity of information systems of banks which operate in the Republic of Croatia.

Based on a bank survey conducted in 2012 by the Croatian National Bank, 25 variables which might indicate higher level of information system complexity were identified and correlated with banks' assets.

High degrees of association were found. This revelation could have implications on banking supervision and, generally, on design of banks' information systems and related control environment.

Keywords. Complexity, bank, information system, IS, IT, size, assets

1 Introduction

Note: The views expressed in this article are those of the author and do not necessarily reflect the views of the Croatian National Bank.

The word „complexity” has an uncanny trait of being interpreted differently in various scientific areas and other fields of human endeavor. The everyday meaning of complexity is „the quality or state of not being simple: the quality or state of being complex” and „a part of something that is complicated or hard to understand” [20]. In the scientific literature complexity is often assumed to be a quality of systems that are characterized by a set of particular characteristics [1]. It is understood that complexity arises from interconnectivity of (numerous) elements and their interaction within a system and environment [21]. Complex systems consist of numerous heterogenous components which are highly connected and are characterized by a strong interaction of those components which in turn have significant impact on system's output [8, 3]. Complex systems are an increasingly popular area of study, especially taking into account societal changes facilitated by advances

in information technology (IT) and increases in its usage. Such systems can breed unexpected results, because in complex systems small changes can have large consequences and large changes can have negligible effects [23].

Because of problems in predictability of their behavior, complex systems have long been seen as sources of significant risk [5]. Based on characteristics of complex systems, Charles Perrow coined the term “Normal accidents” [24]. The idea behind the term is that, as systems become complex, with tightly coupled elements, they also become incomprehensible and partly uncontrollable. Small errors which occur in every system – because of interconnectedness and high degree of interaction in complex systems – cascade into major accidents and finally, into catastrophes. Additionally, because of complexity, implemented controls can only alleviate the consequences, but cannot prevent the occurrence of high-impact accidents. In such environment, accidents are bound to happen and can be considered as “normal”. Therefore – normal accidents. It is important to note that problems arise not only because of design (and complexity) of the system, but also because of wrong or incomplete mental models of the system which prevent prompt corrective or other mitigating actions in case of cascading errors.

The relationship between complexity and technological advances has been an uneasy one. On one side, technology is used to manage complexity, but on the other side it is one of the reasons for increased complexity [16]. Relationship between technological change and rise in complexity is very succinctly described in CERT Resilience Management Model [5, 28]: “More and changing technology often means more complexity. While the automation of manual and mechanical processes through the application of technology makes these processes more productive, it also makes them more complex. Implementation of new technologies can introduce new risks that are not identified until they are realized. And technological advances, while providing demonstrable opportunities for improvements in effectiveness and efficiency, often increase the likelihood that something will go wrong.”

To combat risks inherent to complex systems numerous approaches have been suggested – use of modeling and diversity based approach to testing, change in approach to systems' design, etc. [5]. However, inherently complex organizations and systems first have to recognize their complexity and reasons behind it and then try to estimate risks related to complexity and determine possible mitigation techniques and activities.

This article will explore relationship between the size of banks which operate in the Republic of Croatia and complexity of their information systems.

2 Complexity, bank size and information systems

Complexity of advanced financial instruments and complexity and interconnectedness of financial institutions have been pinpointed as some of the main culprits of the financial crisis which started in 2007. [2] [27]. In the aftermath of the crisis, it was recognized that special attention has to be paid to resilience of large, systemically important institutions [4]. Failure of a systemically important bank can have a very high negative influence on the economy as a whole, so it has to be prevented or adequately dealt with.

From the point of view of regulators and banking supervisors, systemic importance of a bank is often positively correlated or even synonymous to the size of that bank (usually measured through total assets). That is, of all the measures of systemic importance [4], size of assets often has the greatest influence. Some other measures include banks' interconnectedness and banks' "financial" complexity (complexity here primarily relates to complexity of financial instruments and positions). In the case of Croatian banks, those measures of systemic importance [12] are small or even negligible. On the other hand, other indicators show strong market concentration of the larger banks [12] [13] [14, 66-67]. And finally, in line with the article 3. of the Decision on Protective Layers for Structured Systemic Risk [11], Croatian banking regulators identify banks' assets as the key measure of systemic importance of banks operating in Croatia. Hence, it can be concluded that asset size is a good measure of systemic importance of Croatian banks.

In European continental banking tradition (which applies to Croatia, as well) there often is no distinction between commercial and investment banks. Therefore, such – universal – banks provide full scope of banking services to its customers and business models of small and large institutions have similar principles. Hence, there is no need for separating banks into buckets and size of assets criterion can be applied uniformly across the banks.

Market research reports [3] show that banks across the globe rapidly increase number of distribution channels, number of products and their connectedness, which leads to increased complexity of the processes. Furthermore, since most of the changes are driven by advancements in information technology, this increase is especially important for proliferation of complexity in information systems. Information systems (IS) can be viewed as a total of information technology, data and data processing procedures and the people collecting and using these data [10]. Therefore, complexity of information systems surmises technological complexity and organizational complexity related to the technology.

It can be presumed that (for universal banks), the larger a bank's assets are, the more people, technological infrastructure elements, applications and other IS-related resources it uses. On the other hand, it is important to note that banks' ISs are not necessarily built in defensive, safety-critical fashion, which characterizes construction of ISs in areas where human safety is at risk (e.g. automotive industry, health care, defense industry, etc.). Therefore, it can be expected that banks' ISs have a lower level of implemented controls, and hence, a cascade of small errors might not be adequately contained before it becomes a full-blown catastrophe.

Relationship between information technology and complexity has been studied primarily for critical infrastructures [20][22] such as telecommunication companies and energy service providers, but mostly through case studies. It has also been observed that organizational challenges related to technological complexity increase the overall complexity [22].

Influence of technological change on banks has often been studied in the context of reengineering of business processes [15] and proliferation of banking services and distribution channels [3]. However, the risk side of this technological change in banking business is addressed less often.

Recently, issues related to information technology advances and arising complexity in banking have gained more traction. Complexity of information technology and its relationship to business practices in the stock market (including the practices of large banks) has lately been popularized by Lewis [19]. Special report published by the Federal Reserve Bank of New York in March 2014 [7] focuses on large banks' organizational complexity and analyzes influence of, among other things, technological change on banks' business models. However, this newly conducted research focuses mostly on business issues arising from technological complexity, and does not analyze technological complexity in depth nor does it try to quantify it.

To further complicate the matter, it has been recognized that there are no well established measures for complexity [7] and relevant measurable and comparable data is scarce.

3 Information systems in Croatian banks

Even a casual user of banking services in Croatia can observe that Croatian banks are continually increasing number of banking products available to users through direct distribution channels (internet and mobile banking, EFTPOS/ATM networks). Clients can use electronic banking to perform financial transactions in various currencies, arrange deposits, work with payment cards, buy stocks and shares in investment funds, obtain insurance, etc. A prerequisite for provision of those products/services is a high level of technological integration which might also signify high level of complexity. That is, high level of technological integration and provision of wide array of banking products/services to clients presumes copious connections between IT resources, automated exchange of information and existence of numerous automated controls. Furthermore, technology cannot function detached from its environment – people who design, administer and use it, as well as organizational processes through which these activities are performed.

Apart from changes in banking products/services, design and management of banks' ISs is also strongly influenced by banking regulations. Since Croatia is a part of the European Union (EU), EU regulations dominantly shape Croatian regulatory landscape. EU Parliament and other EU entities (e.g. European Banking Authority – EBA) take publications of the Basel Committee on Banking Supervision (BCBS) and transpose them into regulations, guidelines or other publications. Those documents are then directly applied across the EU, transposed into local regulations or used as guidelines (depending on the type of a document). Various regulatory requirements (e.g. risk assessment and modeling, reporting, etc.) influence business processes, functionality of applications, control environment, connections, etc. which, in turn, indicate increased complexity of ISs. Additionally, this is particularly relevant for larger banks which use advanced risk modeling methods.

Issues related to information technology in Croatian banks and other financial services companies have been studied, but mostly through case studies of specific institutions [26] or through (voluntary) surveys. Other research was primarily focused on collection and interpretation of qualitative data related to information systems in banks [25].

Although such research is undoubtedly valuable, it lacks quantifiable, system-wide data which would enable broader conclusions. However, quantifiable and system-wide data on banks is hard to come by, since banks are often unwilling to share data. It can be presumed that this unwillingness stems from the information protection culture related to protection of banking secrecy.

4 Hypothesis

Taking into account indirect indicators stated in the first three chapters, this article will try to verify the following hypothesis, in the case of Croatian banking system: There is a notable positive correlation between the size of banks' assets and complexity of their information systems.

If increase in size of assets is related to increase in complexity, there might be repercussions for banking regulation and supervision, taking into account risks arising from complexity.

Beyond proving or disproving the stated hypothesis, this article should provide measurable, system-wide data on information systems in Croatian banks and present some insights into characteristics of banks' information systems.

5 Collected data and its relevance

Croatian National Bank (CNB) acts as a banking supervisory authority and banking regulator in the Republic of Croatia. It supervises, among other areas, management of risk which arises from the use of information technology in the banks. As a part of the supervision process, CNB periodically collects data on banks' ISs.

In 2012, CNB conducted a survey of credit institution in Croatia (which includes banks). An extensive self-assessment questionnaire was sent to all institutions. The questionnaire collected a wide range of data related to technology, processes, people and financial aspects of ISs. Significant portion of data was quantitative (e.g. number of servers, routers, applications, people, etc.), while qualitative data was structured into ordinal variables (preferably) or other categorical variables. Since the survey was conducted by the banking regulator, all the institutions answered all pertinent questions. Furthermore, institutions' board member responsible for information system vouched for data's completeness and accuracy.

Because of these determinants, collected data is, in essence, census data on information systems in Croatian banks. Furthermore, subselection of data that was used in this study includes only objectively measurable data with no implications on bank's regulatory compliance or adequacy of risk management which, in turn, reduces possibility of untruthful answers. Hence, this data pool could provide a good testing ground for the hypothesis laid down in the previous chapter.

As it was observed in the previous chapters, it is difficult to measure complexity; therefore proxy metrics for complexity will be used. Furthermore, as was also stated, complex systems are characterized by numerous interconnected heterogeneous components. Therefore, the hypothesis will be tested by comparing

size of assets and parameters (variables) which might indicate high complexity of IS. In line with the previously stated definition of IS, these parameters will include technical, organizational/procedural and human aspects.

Data on total assets of individual banks on 31st of December 2012 [9] will be used in the analysis. This variable will be compared with relevant data on IS and correlation coefficients will be calculated. Since the collected data encompasses all the banks which operated on 31st of December 2012 (31 banks and 1 savings bank), it is essentially census data.

Some variables which will be compared to banks' assets denote only one aspect of IS (e.g. number of employees), but most of the data is related to several aspects. The 25 parameters (variables) which will be correlated to banks' assets are:

1. Number (Nr.) of employees
2. Nr. of employees in IT
3. Nr. of personal computers (excluding laptops)
4. Nr. of laptops
5. Nr. of smartphones (officially issued)
6. Nr. of own automated teller machines (ATM)
7. Nr. of own electronic funds transfer at point of sale devices (EFTPOS)
8. Nr. of branches and offices
9. IT budget in 2011 (actual)
10. IT budget in 2012. (plan)
11. Nr. of different business applications
12. Nr. of different IT infrastructure services
13. Nr. of servers (logical units)
14. Nr. of (predominantly) production data centers
15. Nr. of (predominantly) recovery data centers
16. Nr. of used network devices
17. Nr. of producers (makers) of network devices used
18. Nr. of internet-facing demilitarized zones (DMZ)
19. Nr. of internal network segments
20. Nr. of different operating systems used for business applications
21. Nr. of different operating systems used for IT infrastructure services
22. Nr. of different approaches to application development and maintenance
23. Nr. of different approaches to IT infrastructure services maintenance.
24. Nr. of different location models for IT infrastructure services processing
25. Nr. of different location models for application processing

These parameters were chosen based on their availability and implications which they have on the number, interconnectedness and/or heterogeneity of banks' information systems. Relevance of selected variables for the subject of this study is briefly described in the following paragraphs.

Firstly, higher value of any of the selected variables implies higher number of interconnections, which is one of the key characteristics of complex systems. Secondly, higher values of majority of these variables also indicate higher heterogeneity which is also one of the main characteristics of complex systems. Additionally to these generally applicable considerations, particular arguments in favor of positive relationship between higher value of analyzed variables and complexity of IS can be made. Some of those considerations are stated in this chapter.

Number of employees and number of employees in IT denote organizational size. More employees imply more errors, higher compartmentalization of knowledge, potential security awareness problems, higher footprint for social engineering, etc. IT employees often have nonstandard and/or elevated access to systems which also increases administration complexity and possibility of higher impact of unauthorized access.

Number of personal computers should highly correlate with number of employees. Greater number of personal computers has negative implications on administration of end-user devices, provides more entry points for malicious access and errors, etc. Laptops and smartphones provide additional entry points for malicious activities and malicious software and increase controllability issues.

Higher numbers of automated teller machines (ATM), electronic funds transfer at point of sales (EFTPOS) devices, branches and offices all point to more complex network, potential controllability issues, and more opportunities for unauthorized access and errors.

Size of the IT budget does not directly influence information system's complexity, but is an indicator of its magnitude.

Higher number of different business applications could signify higher complexity of IS because different business applications often differ in design, operating characteristics (e.g. look and feel, approach to support of business processes, user manuals, user administration, etc.), change management practices, backup and resumption requirements, approaches to development and maintenance, etc. Of course, applications can greatly differ in size and functionality – one application can contain and perform more tasks than several other applications. However, greater number of applications could point to greater diversity (and heterogeneity) and, in this case, complexity.

Similarly, higher number of distinct IT infrastructure services could signify greater difficulties in administration because of different systems' design, needs for different skills and knowledge, different approaches to administration and maintenance, different resumption and backup requirements, different vendors, etc.

Higher number of servers, production and recovery data centers, used network devices, internet-facing demilitarized zones and internal network segments should point (similarly as ATMs, EFTPOS and branches) to more complex network, potential controllability issues and more opportunities for unauthorized access and errors. Furthermore, they might also indicate issues with administration, physical access problems, difficulties in understanding of different functionalities and security features, etc.

Last 6 variables are somewhat different because of their ordinal character.

In the survey, banks stated types of operating systems used for application and infrastructure systems. These operating systems types can vary significantly (e.g. MS Windows, UNIX, zOS, etc.). In context of this study, the more types of operating systems a bank uses, the more heterogeneous its IS is, because of compatibility issues, need for wider and different knowledge, different logging, security and authorization needs and capabilities, different vendor dependencies, etc.

Development and maintenance of computer business applications can be arranged in various ways. Similarly to previous deliberations, in the context of this study, the more different ways of development and maintenance a bank uses, the more heterogeneous its IS is because of presumable differences in change management requirements and approaches, different standards and procedures, vendor management issues, etc. The following groups of development and maintenance (D&M) arrangements were considered (for each business application), based on experience from banking supervision:

- D&M is performed by the bank
- D&M is performed by a vendor
- D&M is performed by the bank and a vendor
- Development is performed by the bank and maintenance is performed by a vendor
- Development is performed by a vendor and maintenance is performed by the bank
- Other arrangements.

Similarly, maintenance of IT infrastructure services can be arranged in various ways and higher diversity indicates higher complexity of IS. The following groups of maintenance arrangements were considered (for each IT infrastructure service), based on experience from banking supervision:

- Maintenance is performed by the bank
- Maintenance is performed by a vendor (domestic)
- Maintenance is performed by a vendor (foreign)
- Maintenance is performed by the bank and a vendor (domestic).
- Maintenance is performed by the bank and by a vendor (foreign).

Lastly, different groups of processing locations of business applications and IT infrastructure services were considered. Analogous to previous deliberations, greater diversity of ways (locations) in which systems are processed should signify higher complexity because of interconnectedness with other organizations (which in itself significantly increases complexity), different approaches to administration, contracting, legal considerations, etc. The following groups of processing locations were considered (for each application and IT infrastructure service), based on experience from banking supervision:

- Croatia: in the bank
- Croatia: intragroup vendor (part of the banking group).
- Croatia: independent vendor.
- Abroad: mother-bank (owner bank)
- Abroad: intragroup vendor
- Abroad: independent vendor
- Other arrangements.

6 Analysis methods

Pearson r and Spearman ρ (rho) statistical methods will be used as measures of correlation between variables. Spearman ρ is chosen, in addition to more often used Pearson r , because of several reasons. Firstly Spearman ρ is capable of detecting non-linear correlations (although they have to be monotonic, which is in line with the stated objectives of this study). And secondly, Spearman ρ statistic is applicable to ordinal (ranked) data, which is of importance for the last 6 variables. However, the downside of Spearman ρ is somewhat lower statistical power as compared to Pearson r . [17, 261-282]

Since the analyzed data is census data, statistical significance (p) has no meaning and will not be reported.

Interpretation of the effect size varies somewhat among different authors [18]. In this paper, the following interpretation for values of correlation coefficients (absolute values are given) will be assumed:

- [0.0, 0.1) - no association
- [0.1, 0.3) - low association (*)
- [0.3, 0.5) - moderate association (**)
- [0.5, 0.7) - substantial association (***)
- [0.7, 1.0] - very strong association (****)

Taking into account sensitivity and confidentiality of the collected data, in this paper data will be presented only in anonymized, aggregated or some other form which will not impair confidentiality. Hence, correlation diagrams with regression lines will not be displayed.

7 Results and discussion

Results of analysis – correlation coefficients and resulting associations between banks' assets and values of the 25 chosen variables – are given in the table 1.

Table 1. Correlations with banks' assets and size effect interpretations (association)

N.	Variable	Pear. r	Spe. ρ
1.	Nr. of employees	0.99 ****	0.96 ****
2.	Nr. of employees in IT	0.95 ****	0.93 ****
3.	Nr. of personal computers (excluding laptops)	0.98 ****	0.96 ****
4.	Nr. of laptops	0.83 ****	0.69 ***
5.	Nr. of smartphones (officially issued)	0.89 ****	0.61 **
6.	Nr. of own ATMs	0.97 ****	0.95 ****
7.	Nr. of own EFTPOSs	0.83 ****	0.72 ****
8.	Nr. of branches and offices	0.88 ****	0.90 ****
9.	IT budget in 2011 (actual)	0.95 ****	0.77 ****
10.	IT budget in 2012. (plan)	0.97 ****	0.74 ****
11.	Nr. of different business applications	0.73 ****	0.69 ***
12.	Nr. of different IT infrastructure services	0.58 ***	0.60 ***
13.	Nr. of servers (logical units)	0.85 ****	0.80 ****
14.	Nr. of (predominantly) production data centers	0.24 *	0.43 **
15.	Nr. of (predominantly) recovery data centers	-0.02	0.24 *
16.	Nr. of used network devices	0.98 ****	0.95 ****
17.	Nr. of producers of network devices used	-0.08	-0.11 *
18.	Nr. of internet-facing DMZs	0.65 ***	0.47 **
19.	Nr. of internal network segments	0.34 **	0.08
20.	Nr. of different operating systems used for business applications	N/A ¹	0.78 ****
21.	Nr. of different operating systems used for IT infrastructure services	N/A ¹	0.60 ***
22.	Nr. of different approaches to application development and maintenance	N/A ¹	0.43 **
23.	Nr. of different approaches to IT infrastructure services maintenance.	N/A ¹	0.40 **
24.	Nr. of different location models for application processing	N/A ¹	0.48 **
25.	Nr. of different location models for IT infrastructure services processing	N/A ¹	-0.01

Data analysis shows substantial or strong association (if not explicitly stated, positive association and/or correlation is presumed) between assets size and majority of considered variables. For

¹ Pearson r statistic is not appropriate since observed variable is of ordinal (ranked) type.

10 observed variables very strong association was shown via both Pearson r and Spearman ρ methods. Further on, for 6 analyzed variables all calculated correlation coefficients indicated substantial or very strong association.

Especially strong association was found for variables related to organization and distribution channels (nr. of employees and IT employees, nr. of personal computers, nr. of ATMs, EFTPOSs, network devices, branches and offices). This confirms the notion that Croatian banks are universal banks and that organizational size and spread highly correlate with total assets. Financial parameters (budget) also highly correlate with assets. Slightly lower, although still highly significant associations were found between assets and number of laptops and smartphones used.

It is interesting to note substantial or strong association between number of implemented business applications, infrastructure services and assets, which indicates that, although banks are universal in their business type, complexity which arises from the need for business functionality is highly associated with asset size.

Degrees of association between assets and number of data centers are somewhat discordant. It is important to note that banks generally use relatively few data centers – almost 70% of the institutions have one primary and one secondary data center. On the other hand, there are a few institutions with several data centers – hence the discordance.

Number of internet facing DMZs is moderately or substantially associated with assets which might be a sign of better developed internet banking and other direct distribution channels in larger institutions. On the other hand, data on internal network segments is inconclusive.

It is interesting to note a very low association between number of different producers of network devices used and assets, which is the only relevant negative correlation found by this study.

Lastly, relations between analyzed ordinal variables and assets generally show significant association between heterogeneity in operating systems, methods of development and maintenance and locations of processing (out of 6 analyzed relationships, one is very strongly associated, one is substantially associated, 3 are moderately associated, and only in one case there is no association).

There are several potential deficiencies of this study.

First of all, a question could be raised whether the selected variables adequately represent complexity of IS. There are certainly some parameters such as internal complexity of computer applications, control environment and IT governance which might significantly influence the complexity of IS, but were not analyzed in this study. However, such variables were difficult to quantify and compare or were

unavailable. In any case, inclusion of additional variables would not invalidate associations that were found, but would provide further information – although it is possible that notable negative correlations would have been found, which would, in turn, diminish straightforwardness of the conclusions based on the associations described above.

Secondly, assets were correlated with 25 separate variables, but no relationships between those variables were analyzed. Furthermore, no unique (structured) measure of IS complexity was proposed. Such constructs would require more data and more analysis, but could be of great interest and present an opportunity for further research.

8 Conclusion

The results of this study indicate that there exists a significant positive association between size of assets of Croatian banks and complexity of their information systems which, in turn, proves the stated hypothesis.

25 variables which might indicate higher complexity of IS were identified and correlated with size of assets of Croatian banks. 16 of the observed variables were found to be substantially or very strongly associated with banks' assets and further 4 were found to have moderate degrees of association. No variables were found to have a significant negative association with the assets size.

The outcome of this study raises an interesting point for banking supervisors and regulators. As was mentioned, failure of a large, important bank can be extremely damaging for the economy. But, as results of this study show, such banks could be particularly vulnerable to operational errors because of increased complexity of their information systems.

Supervisors and regulators should take a note of that and consider strategies for preventing or at least decreasing probability or impact of occurrence of cascading errors and subsequent catastrophic results.

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